Dynamic Weight Dropping Policy for Improve High-Priority Message Delivery Delay in Vehicular Delay-Tolerant Network

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***Abstract*—Vehicular Delay-Tolerant Network (VDTN) is a special case of Delay-Tolerant Network (DTN) in which connectivity is provided by movement of vehicles with traffic prioritization to meet the requirements of different applications. Due to high node mobility, short contact time, intermittent connectivity, VDTNs use multi-copy routing protocols to increase message delivery rates and reduce the delay. However due to limited resources (bandwidth and storage capacity), these protocols cause the rapid buffer overflow and therefore the degradation of overall network performance. In this paper, we propose a buffer drop policy based on message weight by including traffic prioritization to improve the high priority messages delivery delay. Thus, the memory is subdivided into a high-weight queue and a low-weight queue. When the buffer is overflowing, and a new message arrives, the algorithm determines the message to be dropped in the queues considering that the current node is the destination of the message, the position of the current node with respect to the destination of the message and the age of the messages in the network.**

Keywords—Vehicular delay-tolerant network; dropping policies; traffic differentiation; message weight; high priority message

I. Introduction

Delay-Tolerant Network (DTN) is an environment characterized by intermittent connection, long or variable delays, asymmetric data rates, and high message loss rates [1, 2].

The Vehicular Delay-Tolerant Network (VDTN) is a special case of DTN in which connectivity is provided by nodes (vehicles) with high mobility. The combination of this high mobility and the finite bandwidth, energy constraints and short radio transmission range, causes the short contact duration and intermittent connectivity [3,4]. As a result, to solve the intermittent connectivity problem, vehicles in the VDTN, like the DTN, use the Store-Cary-and-Forward (SCF) mechanism. In addition, to increase delivery rate and reduce delay, VDTNs use multi-copy routing protocols [5-8] that replicate messages across all nodes in the network. However, when the environment is heavily constrained in terms of resources, these excessive replications cause rapid buffer congestion those results in the degradation of overall network performance. Therefore it is important to design buffer scheduling and abort strategies in the VDTN.

VDTNs are used in several areas such as road safety, road traffic management, commercial information dissemination, rural connectivity and as communication media for disaster areas [3,4].As a result, in order to support different applications with different requirements in terms of delivery probability and delivery time, the algorithms take into account three traffic priority classes: low priority for bulk messages, the average priority is normal messages and high priority for expedited messages. However, in order to avoid the resources monopolization by high priority messages at the expense of lower priority messages and to improve the delivery rate of these messages, buffer management strategies propose a message weight metric that does not take into account the priority class of service (CoS) required for VDTN. Therefore, all messages have the same delivery time while the high priority message requires a low delivery delay. As a result, it is necessary to improve the high priority messages delivery delay.

Thus, in this article, we propose a buffer management strategy based on the messages weight in the buffer which not only increases the messages delivery rate whatever the priority of the message but reduces the high priority messages delivery delay. In addition, we use the PRoPHET [8] routing protocol in this study.

The rest of the article is thus organized. Section 2 presents the related work. Section 3 presents the PRoPHET routing protocol. The buffer management strategy is described in section 4. Section 5 presents the discussion. The conclusion and perspectives are presented in section 5.

II. Related Work

As mentioned above, dropping and scheduling buffer policies are needed to increase the delivery rate, reduce delivery delay, and reduce network overhead. In this section, we present work related to the proposed management policy.

Soares and al [9] propose a buffer management system that classifies the messages into three separate queues of high priority, medium priority and low priority messages in order to consider the priority of the service classes. When the buffer becomes congested, the abort strategy removes the low time-to-live (TTL) message from the priority class corresponding to the priority of the incoming message. In addition, the scheduling strategy is based on Custom Service Time (CST), which assigns messages from each priority class based on a fixed percentage of custom time. This strategy avoids the monopolization of resources by high priority messages. However, it reduces the delivery rate of high priority messages.

Penurkar M. R. et al [10], propose a message dropping algorithm based on the message TTL and the messages priority. During this drop policy, the general messages with low-priority are first deleted according to their TTL increasing until TTL threshold. If this space created by deleting these messages is insufficient, then the traffic messages with middle-priority are in turn deleted from their increasing TTL to the TTL threshold. This policy repeats until the high-priority accident message can be inserted into the buffer. This policy despite the fact that it removes old messages of lower priority to reduce the delay and increase the rate of delivery there may be a network overhead caused by the increasing number of old high-priority messages.

More R. A. and Penurkar M. R [11] propose a scheduling policy that transfers messages from priority classes according to the round-robin strategy. In addition, during the drop policy, the low TTL message is first dropped. However, when two messages have the same TTL value, the lower priority message is first dropped. This policy reduces network overhead by removing low TTL messages.

Sadreddini Z. and Afshord in [12], propose General Purpose Buffer Management (GPBM) based on a Multi Criteria Decision Making (MCDM). Thus, to insert a high priority message into a congested buffer, the weighted sum model is used to drop the highest score message. This strategy increases the delivery rate and reduces the delay. However, the determination of the weight of the criteria is not indicated.

The authors in [13] proposed a buffer management policy called WBD (Weight Based Drop Policy) based on local network information. In this article, the message weight is calculated based on the properties of the message, which are its remaining TTL, size, buffer duration, number of hops, and number of replications. The policy divides messages in the node into a high-weight queue and a low-weight queue according to the message weight in the node. When buffer overflows happen, the policy drops the messages in the high-weight queue to receive the new message. If after dropping all messages in the high-weight queue the new message can’t be inserted, then the new message will be ignored in case the current node is not the destination of the message. However, if the current node is the destination of the message, then the messages of the low-weight queue are dropped according to their increasing TTL until the new message is inserted. This strategy has advantages that include protecting recent network messages in the low-weight queue, reducing network overhead by deleting messages in the high-weight queue. However, this strategy does not take into account the hierarchy of the messages on the one hand and on the other hand new messages are ignored despite the fact that they can be inserted in the node by deleting messages from the low weight queue.

Wang H. et al [14] propose a buffer management system called NWBBMP (Novel Weight-Based Buffer Management Policy) that divides messages in the buffer into a queue of priority messages consists of recent messages in the buffer that can’t be dropped, a low-weight queue and a high-weight queue. In addition, the system combines the Weight Based Drop Policy (WBD) [13] and OBM (Optimal Buffer Management) policies [15] to drop messages from the high-weight queue and messages from the low-weight queue on whether or not the current node is the message destination to improve network performance. This strategy based on the global information of the network whose acquisition is difficult. However, it has advantages that include protecting recent messages in the buffer, reducing delay, reducing network overhead, and increasing the delivery rate. However, this strategy does not take into account the hierarchy of messages.

Based on the analysis of the strategies above, combining the benefits and making improvements, we propose a new buffer management system. This system is based on the local network information and takes into account the priority class of the message. In the next section, we present the PRoPHET routing protocol used in this study.

III. PROPHET ROUTING PROTOCOL

PRoPHET (Probabilistic Routing Protocol using History of Encounters and Transitivity) [8] is a probabilistic routing protocol that uses the node's encounter history and transitivity to determine the best relay node by calculating the delivery predictability of the message, *P (a, b)*, where *a* is the node carrying the message and *b* is the destination. From the frequent node encounters, the node calculates the probability of delivery based on a high probability of meeting again in the future. The delivery probability is given by equation (1).

$$P_{(a,b)} = P_{(a,b)old} + (1 - P_{(a,b)old}) \times P_{init} \quad (1)$$

Where $P_{(a, b)}$ is the encounter probability of the nodes a and b, $P_{(a, b)old}$ is the old probability and P_{int} is the initial probability.

In addition, PRoPHET uses aging that describes the fact that a node with a large time interval of encounters should not be encountered in the future.

As a result, this reduces the probability value as a function of the time interval and the aging constant. The aging constant γ determines the reduction ratio and is represented as in equation (2).

$$P_{(a,b)} = P_{(a,b)old} \times \gamma^{k} \quad (2)$$

Where k represents the number of time slots between the nodes encountered.

In addition, PRoPHET uses the transitivity which describes the fact that the node C is the best destination of the node A if the node A has frequently met the node B and the node B has frequently met the node C. This transitivity is described by the equation 3.

$$P_{(a,c)} = P_{(a,c)old} + (1 - P_{(a,c)old}) \times P_{(a,b)} \times P_{(b,c)} \times \beta \qquad (3)$$

Where β is the transitivity factor used to bound the probability between three nodes A, B and C.

In general, PROPHET routing considering tradeoffs between its performance in terms of delivery ratio, delay, and node resource limitations in terms of energy and storage.

The following section presents the proposed buffer management policy.

IV. Proposed Buffer Management Policy

This section first introduces the preliminaries used to develop our buffer management strategy, then the distribution of messages in the queues and finally the details of the proposed policy.

A. Preliminaries

VDTN is a network characterized by a high mobility of vehicles. This high mobility results in short contact times, intermittent connectivity, and frequent changes in the topology of the vehicular network. Therefore, the vehicle mobility model has a direct impact on the message transmission opportunities and the vehicles inter-contact time of the vehicles.

In this paper, we assume that the number of vehicles follows a Poisson distribution of parameter λ [16]. Thus the inter-contact time follows an exponential distribution of parameter λ with λ = 1/E[X] where E[X] is the average encounter time. In addition, we assume that message transmission occurs when the vehicles are within communication range of each other and all vehicles have the same limited size of the buffer.

In this study, we assume that an incoming high priority message is recent in the network than another message in the low-weight queue if the sum of its hop count and its number of replications is less than the sum of the hop count and the number of replications of the new high priority message given by (4).

$$Hc_M + Rc_M \ < \ Hc_i + Rc_i \qquad (4)$$

Where Hc_M and Rc_M are respectively the hop count and replication numbers of the incoming high priority message. And Hc_i and Rc_i are respectively the numbers of hops and replications of a message in the low-weight queue.

Furthermore, in this study, in addition to the predictability of delivery given by PRoPHET, we use the position and direction of a node given in [17].

Let $\overrightarrow{V_M}$, the velocity vector of a node M moving or not towards the destination D. The angle θ given by the equation (5) allows to determine if M moves or not towards the destination D.

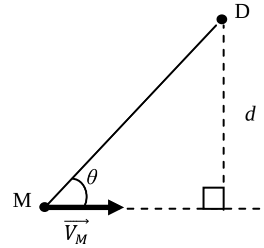

Fig. 1. Moving a Node.

$$\theta \ = \ \cos^{-1}\left(\frac{\overrightarrow{MD} \times \overrightarrow{V}_M}{\left|\overrightarrow{MD}\right| \times \left|\overrightarrow{V_M}\right|}\right) \qquad (5)$$

Thus, when the angle θ < 90°, the node moves to the destination. And the expected minimum distance d_{min} is given by equation (6).

$$d_{\min} = \ \min\{d(M;D)\} = \sin\theta \times \left|\overrightarrow{MD}\right| \qquad (6)$$

Fig. 1 below illustrates the displacement of a node relative to the destination.

In our study, among the multitude of candidate neighbor nodes, the node with the highest predictability of delivery and located at a distance less than or equal to the minimum distance to the destination is defined as the node closest to the destination.

In other words, a node A which has the greater delivery predictability with respect to another node B is far from the destination if its distance to the destination is greater than the minimum distance. The following equations give the greater delivery predictability and position of the node relative to the destination. Thus, we have:

$$P(A;D) > P(B;D) \qquad (7)$$

The node is far from the destination if

$$d(A;D) > d_{\min} \qquad (8)$$

The node is close to the destination if

$$d(A;D) \leq d_{\min} \qquad (9)$$

B. Messages Classification in Queues

As in the literature [13], this paper admits in each node the division of the messages in the buffer into a low-weight queue and a high-weight queue as shown in fig. 2.

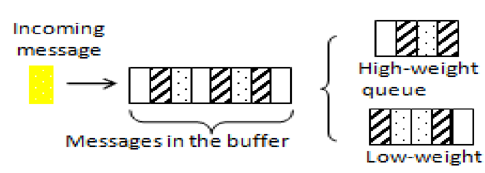

Fig. 2. Buffer Architecture.

The low-weight queue and the high-weight queue are defined according to [14]. Thus, if the message weight is greater than the average message weight in the buffer, then this message is placed in the high-weight queue. Otherwise, this message is placed in the low-weight queue. The message weight is given by equation (10).

$$\omega_i = Hc_i + Rc_i + \frac{1}{T_i} + \frac{1}{S_i} + \frac{1}{TTL_i} + \frac{1}{P_i} \qquad (10)$$

Where Hc_i is hop count, Rc_i is the replication count, T_i is the message buffer time, S_i is the size, TTL_i is the remaining TTL and P_i is the message priority.

The average messages weight in the buffer is given by equation (11).

$$\bar{\omega}_M = \frac{1}{n(t)} \sum_{i=1}^{n(t)} \omega_i \qquad (11)$$

Where $n(t)$is the amount of all messages in the buffer at time t.

C. Operation of the Propose Drop Policy

In this model, we first check if the size of the free space (FS) is larger than the size of the new message. Thus, if this is the case, then the new message is inserted according to its weight in the corresponding queue if the current node is or is not the destination of the message.

Moreover, if the FS is insufficient, then the drop policy is applied taking into account that the current node is an intermediate node or is the destination of the message. In addition, when the current node is an intermediate node, the drop policy is applied taking into account the priority of the incoming message and the position of the current node with respect to the destination.

Thus, if the current node is the destination of the message, and if the sum of the size of the FS and the space occupied by the messages of the high-weight queue (HWQ) is greater than the size of the incoming message, then the messages of the HWQ are deleted according to their decreasing weight. And the new message is inserted. However, if two HWQ messages have the same weight, then the lower priority message is dropped first. However, if this sum is smaller than the size of the incoming message, then the messages of the low-weight queue (LWQ) are dropped according to the decreasing TTL (TTL Time-To-Live) until the new message is inserted. However, if two LWQ messages have the same TTL, then the lower priority message is dropped first.

On the other hand, if the current node is an intermediate node that is not closest to the destination, and if the sum of the size of the FS and the space occupied by the HWQ messages is greater than the incoming message size, then the HWQ messages are dropped according to the decreasing weight. However, if this sum is less than the size of the incoming high-priority message, and the high-priority message is recent than the LWQ message, then the LWQ message must be dropped. And insert the high- priority message. However, in each case, if two messages have the same value of the characteristic, then the lower priority message is first dropped. The Flow chart of the proposed policy is illustrated in Fig. 3.

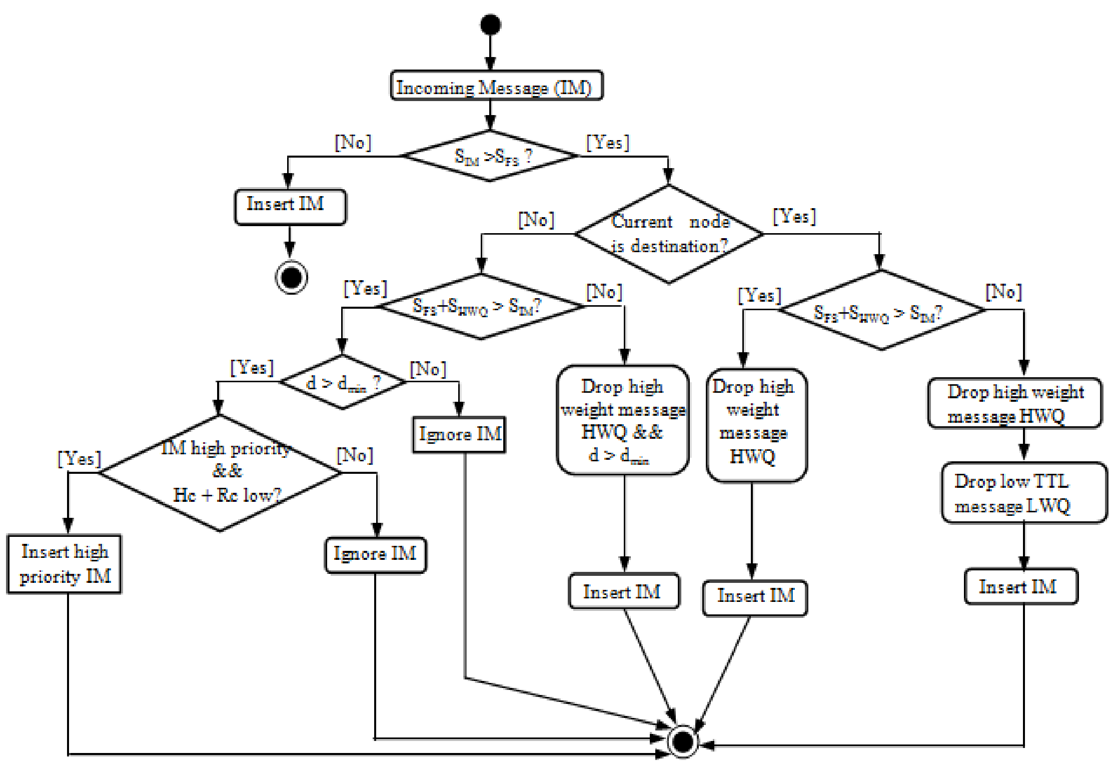

Fig. 3. The Flow Chart of the Proposed Policy.

V. Discussion

The dissemination of high priority messages in the VDTNs is generally done using the size of the message, its time-to-live, its priority or its number of forwarding. In our case, we are interested in reducing the delay of delivery of high priority message taking into account the local information of the network grouped in the expression of the message weight, the position of the current node and using Prophet routing protocol.

A message of high priority has its size which is between 750KB and 1, 5MB on the one hand and on the other hand the value of the priority P = 3. A medium priority message has its size between 250KB and 750KB on the one hand and on the other hand the priority value is P = 2. A low priority message has a size between 100 KB and 250 KB on the one hand and on the other hand the priority value is P = 1. [12]

Assuming the values the values of hop count, the replication count, the message buffer time and the time-to-live present in the weight expression are identical for each of the priority classes, then the high priority message has the smallest weight value. Therefore, the high priority message is first forwarded. Thus, its delivery delay is lower than that of the lower priorities.

In addition, the model favors the insertion of a higher priority message that is newer than the messages of the low-weight queue when the current node is not the destination of the message in order to increase not only the rate delivery but also to reduce the delivery delay of the high priority message with respect to the lower priority messages.

Moreover, if the different strategies do not take into account the position of the current node with respect to the destination, any message whose node will be close to the destination can be dropped. Therefore, this will cause an increase in the delivery delay of the messages and in particular the high priority message.

However, in our model, when the current node is an intermediate node, and deciding to delete a message in this node that is far from the destination, the delivery time of all messages decreases. Since the high priority message has the smallest weight, its delivery delay will be even smaller.

VI. Conclusion

In this article, we analyzed several buffer management policies to propose an algorithm to improve the delivery delay of high priority messages by using the local network information and the priority class of service. Thus, the proposed algorithm drops the message in the low-weight queue and high-weight queue depending on whether or not the current node is the destination of the new message, depending on whether the intermediate node is not the destination closest node and the age of the message. The high priority message is forwarded well before the lower priority messages.

Our work is of course opened. In the future, we plan to analyze the behavior of this model using other routing protocols such as the epidemic protocol and the Spray and Wait protocol.

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